Sampling Episode Report
Holland America Oosterdam
Sampling Episode 6506

Chapter 2
Wastewater System and Sampling Points

March 2006

2.0 WASTEWATER SYSTEM AND SAMPLING POINTS

This section describes graywater and sewage generation, collection, and treatment on the Oosterdam, as well as the sample collection points and flow meter locations and installation points used in this sampling episode.

2.1 Wastewater Generation and Collection

The ship's collection, holding, and transfer system (CHT) collects and transfers graywater and sewage generated onboard to the ship's ROCHEM graywater and sewage/graywater treatment systems or to overboard discharge. For the purpose of this report, graywater refers to non-sewage wastewaters that are collected by the CHT system. The CHT system is composed of five subsystems, referred to by the ship's crew as the galley, food pulper, accommodations, laundry, and sewage systems. Figure 2-1 is a simplified diagram of the Oosterdam's graywater and sewage CHT system. Wastewater sources collected by each of the five subsystems are described in Table 2-1. Potable water is used as source water for all ship operations that generate graywater and sewage (e.g., laundry, galley, food pulper, sinks, showers, and toilets). Potable water is produced onboard and seldom bunkered while in port.

2.2 Wastewater Treatment

Wastewater treatment onboard the Oosterdam is composed of two different types of ROCHEM systems designed to treat low concentration wastewater and high concentration wastewater separately. Low concentration wastewater (laundry and accommodations wastewater) are routed to the ROCHEM graywater treatment system (see Section 2.2.1 below), and high concentration wastewater (passenger and crew galley wastewater, sewage, and membrane concentrate from the ROCHEM graywater treatment system) are routed to the ROCHEM sewage/graywater treatment system (see Section 2.2.2 below). Effluent from the two treatment systems are combined for discharge overboard through a single port. Figure 2-2 is a simplified diagram of the ROCHEM graywater treatment system and Figure 2-3 is a simplified diagram of the ROCHEM sewage/graywater treatment system.

2.2.1 ROCHEM Graywater Treatment System

The Oosterdam is outfitted with a ROCHEM LPRO treatment system (referred to in this report as the ROCHEM graywater treatment system), an advanced wastewater treatment system that uses low pressure reverse osmosis followed by ultraviolet (UV) disinfection to treat low concentration wastewater (i.e., accommodations and laundry wastewater). Figure 2-2 is a simplified diagram of the ROCHEM graywater treatment system.

Wastewater from the accommodations and laundry CHT subsystems culminates in three graywater holding tanks. From the graywater holding tanks, the wastewater is pumped through a vibratory screen filter (mesh size 104 µm) to remove coarse solids such as fibers, hair, and large sediment (the system has two filters, which alternate operation each month). After the vibratory screen filter, antiscale chemicals are added and the wastewater is filtered using a bag filter to prevent fouling or blockage of the subsequent reverse osmosis membranes. Next, the wastewater passes through two trains of reverse osmosis membrane units operated in parallel. Together, the two trains contain a total of 80 individual reverse osmosis modules organized in multiple sets or blocks of 8. The reverse osmosis modules use cross flow design (wastewater flows parallel to membrane surface) to minimize fouling. Membrane permeate (85% of treatment system influent by volume) collects in small permeate tanks (one tank for each train), while membrane concentrate (15% of treatment system influent by volume) is routed to the ROCHEM sewage/graywater treatment system for further treatment (see below). Sodium hydroxide is added to the permeate for pH control as it is pumped from the permeate tanks to the final stage of treatment, UV disinfection. The hydraulic residence time of the treatment system (i.e., the amount of time the wastewater stays in the treatment system) is approximately 12 hours.

The ROCHEM graywater treatment system is also equipped with a second stage of reverse osmosis membranes and permeate tanks designed to operate in series with the first stage described above. However, treated wastewater from the first stage bypasses these components of the system as they are not needed to achieve Holland America's effluent quality requirements. The second stage membranes are arranged in two parallel trains with a combined

total of 40 reverse osmosis modules. The second stage can be used in emergency situations, such as during upset or maintenance of the first stage.

According to the ship's crew, the ROCHEM graywater treatment system can treat approximately 650 m^3 (172,000 gallons) per day of low concentration wastewater. During the sampling episode, the average daily load to the system was 307 m^3 (81,000 gallons), as determined by measured flows collected by the sampling crew.

The ROCHEM graywater treatment system operates continuously, regardless of the ship's location (e.g., in port, at sea within Alaska waters, at sea outside Alaska waters). The vessel typically continuously discharges treated wastewater from this system overboard. When overboard discharge is suspended, such as when the ship cruised Hubbard Glacier, the treated effluent is diverted to double-bottom holding tanks, where it is held for eventual discharge outside of 12 nautical miles (nm) from shore.

The ROCHEM graywater treatment system generates two types of residuals: screening solids (from the vibratory screen filter) and spent bag filters. Screening solids (approximately 20 gallons per day) are collected manually and disposed of in the incinerator system. Four spent filter bags are generated each day and are shredded and incinerated onboard.

The graywater system is cleaned when transmembrane pressure exceeds 5 bars (approximately every 600 hours). The membranes soak in caustic and then acid cleaning solutions for 45 minutes and are then rinsed. Spent cleaning solutions and rinse water are routed to the ROCHEM sewage/graywater treatment system for treatment. The individual reverse osmosis modules in the treatment system are placed in standby mode while in the cleaning sequence. Occasionally, the membrane modules undergo a more aggressive chemical soak similar to that described in Section 2.2.2 for the ROCHEM sewage/graywater treatment system.

2.2.2 ROCHEM Sewage/Graywater Treatment System

The Oosterdam is outfitted with a ROCHEM Bio-Filt® treatment system (referred to in this report as the ROCHEM sewage/graywater treatment system), an advanced wastewater treatment system that uses aerobic biological oxidation followed by ultrafiltration and UV disinfection to treat high concentration wastewater (sewage, galley wastewater, and membrane concentrate generated by the ROCHEM graywater treatment system). Figure 2-3 is a simplified diagram of the ROCHEM sewage/graywater treatment system.

Wastewater from the galley and sewage CHT subsystems culminates in two buffer tanks, the first component of the ROCHEM sewage/graywater treatment system. Membrane concentrate from the ROCHEM graywater treatment system is also routed to the buffer tanks. Wastewater is pumped between the two buffer tanks to produce a homogeneous influent to the treatment system. An antifoam chemical is added to the recirculation loop. From the buffer tanks, the wastewater is pumped through a vibratory screen filter (mesh size 104 μm) to remove coarse solids (the system has two filters, which alternate operation each month). Filtered wastewater collects in a filtrate tank, where sodium hydroxide is added to control pH.

From the filtrate tank, the wastewater is pumped to eight aerated bioreactor/ ultrafiltration membrane treatment trains operated in parallel. Each bioreactor/ultrafiltration train consists of eight segments of bioreactors and nine membrane modules. The bioreactor segments operate in parallel while the ultrafiltration modules are arranged in both parallel and serial formation (three sets of modules operate in series with each set consisting of three modules operated in parallel). (Note that ROCHEM personnel and the ship's crew refer to the treatment trains as "blocks," with two blocks in a "stage" and two stages in a "line," for a total of two lines.)

The ultrafiltration modules use cross flow design (wastewater flows parallel to membrane surface) to minimize fouling. Membrane permeate (10 to 15 % of treatment system influent) collects in small permeate tanks (one tank for each train). Membrane concentrate (85 to 90% of treatment system influent), consisting of particulate matter and mixed liquor (wastewater

containing organic matter and biological floc), is returned to the bioreactors. This pressurized return stream also serves as the mechanism for bioreactor aeration and mixing by driving eductor pumps that take in air which is then released as fine bubbles in the bioreactors. A transmembrane pressure of 4 bars is required for proper operation.

Combined wastewater from the permeate tanks undergoes UV disinfection as the final stage of treatment. The hydraulic residence time of the treatment system is less than one day.

According to the ship's crew, the ROCHEM sewage/graywater treatment system can treat approximately 330 m^3 (87,200 gallons) per day of high concentration wastewater. During the sampling episode, the average daily load to the system was 227 m^3 (59,900 gallons), as determined by measured flows collected by the sampling crew.

The ROCHEM sewage/graywater treatment system operates continuously, regardless of the ship's location (e.g., in port, at sea within Alaska waters, at sea outside Alaska waters). The vessel typically continuously discharges treated wastewater from this system overboard. When overboard discharge is suspended, such as when the ship cruised Hubbard Glacier, the treated effluent is diverted to double-bottom holding tanks, where it is held for discharge outside of 12 nautical miles (nm) from shore.

The ROCHEM sewage/graywater treatment system generates two types of residuals: screening solids (from the vibratory screen filter) and waste biosludge (excess biological mass from the bioreactors). Screening solids (approximately 50 gallons per day) are pumped from the filter's solids collection tank to a double-bottom holding tank for discharge outside of 12 nm from shore. Waste biosludge is removed (or "wasted") from the bioreactors to maintain a constant biomass concentration in the bioreactors. The typical wasted biosludge volume is approximately 25 m^3 per day and is determined by measuring the bioreactor total suspended solids (mixed-liquor suspended solids (MLSS) concentration. The target MLSS

concentration is 15,000 mg/L. Waste biosludge is held in a double-bottom holding tank for discharge outside of 12 nm from shore.

While the cross-flow design minimizes membrane fouling, solids accumulate on the membrane surface, which increases transmembrane pressure and reduces permeate production. The system backwashes the membranes every 40 minutes to keep the membranes clean; this backwash remains in the system. In addition, air is periodically introduced from the permeate side to physically remove solids from the membrane surface. The ultrafiltration membranes are also chemically cleaned when transmembrane pressure reaches 5 bars (approximately every 600 hours). The cleaning cycle takes a full day. During the cleaning process, two different chemicals are cycled through the modules in both forward and reverse directions: caustic for five hours and then acid for four to five hours. Finally, the modules are rinsed with fresh water to avoid any contamination of the bioreactors with cleaning agents. Spent cleaning solutions and rinse water are routed to a double-bottom holding tank (the same tank as for waste biosludge) for discharge outside of 12 nm from shore. During the cleaning cycle, the bioreactor/ultrafiltration stage is in stand-by mode, and all wastewater is diverted to other bioreactor/ultrafiltration stages. While in stand-by mode, the eductor system on that stage does not operate; air spargers located at the bottom of the bioreactors provide sufficient air supply and mixing to maintain the microorganisms.

2.3 Graywater, Sewage, and Residual Sample Collection Points

Samples were collected from the graywater source (accommodations, laundry, galley, food pulper), influents to the treatment systems, influents to the UV disinfection portion of the treatment systems, effluents from the treatment systems, source water (water from the ship's potable water system), wastewater treatment residuals, and incinerator ash. Table 2-1 describes the wastewaters sampled, their sampling point locations, their flow measurement locations (if applicable), and the number of days they were sampled. Table 2-2 provides the same information for the treatment residuals and incinerator ash sampled. In general, graywater and wastewater treatment residual samples were taken for one 24-hour period, while samples of

the influents to and effluents from the treatment systems were taken for five 24-hour periods. See Section 3.2 and Table 3-2 for information on the analytes tested.

Samples were collected from the ship's potable water system (source water) to determine if any of the target analytes were present as background contamination. One trip blank was prepared and analyzed for volatile organics to evaluate possible contamination during shipment and handling of samples. Finally, an equipment blank was prepared and analyzed to evaluate possible contamination by the sampling equipment.

Samples were not taken directly from the sewage CHT system. In addition, samples could not be collected of wastewater held in double-bottom holding tanks for discharge outside 12 nm from shore (i.e., treated effluent diverted to storage while the ship cruised Hubbard Glacier) because (1) double-bottom holding tanks cannot be accessed directly due to safety consideration, and (2) sampling from the holding tank discharge manifold would characterize combined holding tank discharges and not discharges specific to the holding tanks of interest.

2.4 Flow Meter Locations

Strap-on ultrasonic flow meters (Controlotron Model 1010) were installed at six sampling locations to collect flow data and, in some cases, to control an automatic composite sample machines (by triggering sample collection after a defined amount of flow passed through the pipe). The first location was on the outlet pipe from one of the accommodations holding tanks (accommodations wastewater, SP-1; see Table 2-1 for a description of wastewaters and Figure 2-1 for a simplified graywater and sewage CHT system diagram showing sampling points and flow meter locations). The second location was the at the influent to the graywater treatment system on the combined graywater inlet pipe to the vibratory screen filter (SP-6; see Table 2-1 and Figure 2-2). The flow meter at SP-6 could not be used to trigger collection of flow-weighted composite samples because high wastewater pressure caused continuous collection of sample when the sample tap was left open. Instead, influent to graywater treatment system samples were collected as grab composite samples (see Table 3-1 for a description of sample collection

methods). The third location was at the effluent from the graywater treatment system on the outlet pipe from the UV disinfection unit (SP-8/9; see Table 2-1 and Figure 2-2). This flow meter collected flow data and triggered collection of flow-weighted composite samples through the end of Day 3 of sampling. At this time, high wastewater pressure caused the flow meter to lose signal strength. Repeated attempts to run the flow meter set-up and calibration procedures were unsuccessful. Flow data for sampling Days 4 and 5 were not collected and the corresponding samples were collected as grab composite samples.

The fourth location was at the influent to the sewage/graywater treatment system on the inlet pipe to the vibratory screen filter (SP-11; see Table 2-1 and Figure 2-3). The fifth location was the effluent from the sewage/graywater treatment system on the outlet pipe from the UV disinfection unit (SP-13/14; see Figure 2-3). The final location was the final combined effluent from the graywater and sewage/graywater treatment systems on the overboard discharge line (SP-16; see Table 2-1 and Figures 2-2 and 2-3).

Sampling points for galley and laundry wastewaters were located on piping that would not support the installation of strap-on ultrasonic flow meters (see Table 2-1), precluding collection of flow data and flow-weighted composite samples at these sampling points. Time-weighted composite samples were collected at the galley and laundry wastewater sampling points (see Table 3-1 for a description of the sample collection methods). Flow estimates for the food pulper wastewater were provided by the ship's crew.

Table 2-1

Wastewater, Sampling Point, and Flow Meter Descriptions, Holland America Oosterdam

Descriptions of wastewaters sampled, sampling point locations, flow meter locations, and number of days sampled for the Oosterdam sampling episode (September 18 through September 23, 2004).

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Accommodations	Wastewater from sinks, tubs, and showers in guest and crew rooms, bar sinks, salon sinks and floor drains, medical sinks and floor drains, most interior deck drains, and non-engine room shop sinks. Accommodations wastewater drains to five accommodations wastewater holding tanks approximately equal in size.	SP-1	Sample tap was installed on the outlet pipe from one of the holding tanks. According to the ship's crew, all six holding tanks receive similar wastewater; therefore, the specific holding tank sampled was selected based on accessibility.	Strap-on flow meter was installed on the outlet pipe from one of the accommodations wastewater holding tanks (the same discharge line as the installed sample tap).	1 (Day 3)
Laundry	Wastewater from laundry equipment and laundry floor drains. All laundry wastewater drains to a single laundry holding tank. Discharge pumps for the laundry holding tank activate by both a liquid level indicator and a timer to provide relatively constant flow to the ROCHEM graywater treatment system.	SP-2	Sample tap was installed on the outlet pipe from the laundry wastewater holding tank.	Flow data for laundry wastewater were not obtained. Strap-on flow meter set-up and calibration procedure was unsuccessful on the outlet pipe from the laundry wastewater holding tank, most likely due to close proximity to pumps and other sources of turbulence. Pipe configurations precluded all other locations.	1 (Day 1)
Galley	Wastewater from dishwashers, food preparation, galley sinks, galley deck drains, and galley floor washing (typically hand mops). Galley wastewater drains through grease traps into two galley holding tanks (one for the crew galley and one for the two passenger galleys).	SP-3	Sample tap was installed on the inlet pipe to the crew galley grease tap. According to the ship's crew, both grease traps receive similar wastewater; therefore, the specific grease trap sampled was selected based on accessibility.	Flow data for galley wastewater were not obtained. Strap-on flow meter was not suitable for gravity flow piping (i.e., piping that is not full) at the inlet to the grease trap. Pipe configurations precluded all other locations.	1 (Day 2)

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1, 2-2, and 2-3 for simplified diagrams of the Oosterdam graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations. Food Pulper Wastewater, Vacuum System (SP-4) is not listed in this table as samples could not be collected from this sampling location (see Table 3-5).
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-4 and 5-5 for details on duplicate sampling.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Food Pulper, Centrifuge System	Wastewater from the centrifuge food pulper system (one of two food pulper systems on the Oosterdam). Food waste is mixed with water and processed into a slurry. The food slurry is then separated into semi-dry food solids and wastewater (food pulper wastewater) using a centrifuge. Food solids are incinerated onboard, while food pulper wastewater is recirculated within the food pulper system. Once per day the food pulper wastewater is drained from the centrifuge to a drain tank and replaced with fresh water. The drain tank has additional inlet pipes to receive wastewater from a second food pulper system (not operated during the sampling episode), as well as waste from galley grease traps.	SP-5	Sample tap was installed on the food pulper centrifuge system outlet pipe (i.e., the inlet pipe to the drain tank).	Flow measurements not required. Approximately 8 to 10 m^3 of food pulper wastewater is generated per day from the two food pulper systems, according to the ship's crew.	1 (Day 5)
Influent to ROCHEM Graywater Treatment System	Combined wastewaters from the accommodations and laundry collection, holding, and transfer (CHT) subsystems. Wastewater from the accommodations and laundry CHT subsystems culminates in three graywater holding tanks.	SP-6	Sample tap was installed on the combined graywater inlet pipe to the treatment system (before the vibratory screen filter).	Strap-on flow meter was installed on the combined graywater inlet pipe to vibratory screen filter (the same inlet/pipe as the installed sample tap). Flow meter could not be used to trigger collection of flow-weighted composite samples because of high wastewater pressure.	5
Influent to UV Disinfection part of the ROCHEM Graywater Treatment System	Graywater following treatment by reverse osmosis but prior to ultraviolet (UV) disinfection.	SP-7	Sample tap was installed on the inlet pipe to the UV disinfection unit.	Flow measurements not required.	5

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1, 2-2, and 2-3 for simplified diagrams of the Oosterdam graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations. Food Pulper Wastewater, Vacuum System (SP-4) is not listed in this table as samples could not be collected from this sampling location (see Table 3-5).
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-4 and 5-5 for details on duplicate sampling.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Effluent from ROCHEM Graywater Treatment System	Final treated graywater effluent from the ROCHEM graywater treatment system. Effluent from the ROCHEM graywater treatment system is combined with effluent from the ROCHEM sewage/graywater treatment system and is typically continuously discharged overboard. Where discharge is prohibited, the combined effluent is diverted to storage tanks for overboard discharge outside 12 nm from shore.	SP-8/9	Sample tap was installed on the outlet pipe from UV disinfection unit, close to the unit and upstream of where the graywater effluent is combined with sewage/graywater effluent for overboard discharge. Piping distance from the graywater effluent sample tap to the overboard discharge port is 30 m.	Strap-on flow meter was installed on the outlet pipe from UV disinfection, close to the unit and upstream of where the graywater effluent is combined with sewage/graywater effluent for overboard discharge (the same outlet pipe as the installed sample tap). Flow data for the effluent from the ROCHEM graywater treatment system were collected through Day 3 of the sampling episode, but were not obtained on Days 4 and 5. At the end of Day 3, high wastewater pressure caused the flow meter to lose signal strength. Repeated attempts to run the flow meter set-up and calibration procedures were unsuccessful.	5
Influent to ROCHEM Sewage/Graywater Treatment System	Combined wastewaters from the galley and sewage CHT systems. Also includes reverse osmosis concentrate from the ROCHEM graywater treatment system. Wastewater from the galley and sewage CHT subsystems culminates in two buffer tanks, the first component of the ROCHEM sewage/graywater treatment system. Reverse osmosis concentrate from the ROCHEM graywater treatment system is also routed to the buffer tanks. Wastewater is pumped between the two buffer tanks to produce a homogeneous influent to the treatment system.	SP-11	Sample tap was an existing sample tap installed on the recirculation loop that mixes wastewater from the two buffer tanks.	Strap-on flow meter was installed on the inlet pipe to the vibratory screen filter.	5
Influent to UV Disinfection part of ROCHEM Sewage/Graywater Treatment System	Wastewater following treatment by biological oxidation and ultrafiltration but prior to UV disinfection.	SP-12	Sample tap was installed on the inlet pipe to the UV disinfection unit.	Flow measurements not required.	5

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1, 2-2, and 2-3 for simplified diagrams of the Oosterdam graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations. Food Pulper Wastewater, Vacuum System (SP-4) is not listed in this table as samples could not be collected from this sampling location (see Table 3-5).
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-4 and 5-5 for details on duplicate sampling.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Effluent from ROCHEM Sewage/Graywater Treatment System	Final treated sewage/graywater effluent from the ROCHEM sewage/graywater treatment system. Effluent from the ROCHEM graywater treatment system is combined with effluent from the ROCHEM sewage/graywater treatment system and is typically continuously discharged overboard. Where discharge is prohibited, the combined wastewater is diverted to storage tanks for overboard discharge outside 12 nm from shore.	SP-13/14	Sample tap was installed on the outlet pipe from the UV disinfection unit, close to the unit and upstream of where the sewage/graywater effluent is combined with graywater effluent for overboard discharge. Piping distance from the sewage/graywater effluent sample tap to the overboard discharge port is 45 to 50 m.	Strap-on flow meter was installed on the outlet pipe from the UV disinfection unit, close to the unit and upstream of where the sewage/graywater effluent is combined with graywater effluent for overboard discharge (the same outlet pipe as the installed sample tap).	5
Final Combined Treated Effluent	Combined treated effluent from the graywater and the sewage/graywater treatment systems. Combined effluent is typically continuously discharged overboard. Where discharge is prohibited, the combined wastewater is diverted to storage tanks for overboard discharge outside 12 nm from shore.	SP-16	Sample tap was installed on the overboard discharge line, downstream of where graywater and sewage/graywater effluents are combined and downstream of the diversion valve that directs wastewater to either overboard discharge or storage in double-bottom holding tanks. Piping distance from the combined effluent sample tap to the overboard discharge port is <1 m.	Strap-on flow meter was installed on the overboard discharge line, downstream of where graywater and sewage/graywater effluent and combined and downstream of the diversion valve that directs wastewater to either overboard discharge or storage in double-bottom holding tanks (the sample discharge line as the installed sample tap).	5
Source Water	Potable water used as source water for all systems that generate wastewater that is treated by the ROCHEM graywater and sewage/graywater treatment systems.	SP-17	Samples collected from a bathroom sink in a sampling team member's cabin.	Flow measurements not required.	1 (Day 2)

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1, 2-2, and 2-3 for simplified diagrams of the Oosterdam graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations. Food Pulper Wastewater, Vacuum System (SP-4) is not listed in this table as samples could not be collected from this sampling location (see Table 3-5).
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-4 and 5-5 for details on duplicate sampling.

Table 2-2

Treatment Residual and Incinerator Ash Descriptions, Holland America Oosterdam

Treatment Residual Name	Treatment Residual Description	Sampling Point # (a)	Sampling Point Description (a)	Flow Meter Description (a)	# Days Sampled
Incinerator Ash	Ash generated from the incineration of trash (e.g., cardboard, paper, plastic), food solids from the food pulper systems, ROCHEM sewage/graywater screening solids, and spent bag filters. Incinerator ash is collected in incinerator ash storage hoppers for disposal onshore.	SP-10	Samples were collected directly from an incinerator ash storage hopper.	Flow measurements not required.	1 (Day 5)
Graywater Screening Solids	Solids generated by the vibratory screen of the ROCHEM graywater treatment. Screening solids are collected manually and disposed of in the incinerator system for discharge outside of 12 nm from shore.	SP-15	Samples were collected directly from a plastic screening solids storage container.	Flow measurements not required. Approximately 20 gallons of graywater screening solids are generated per day, according to the ship's crew.	1 (Day 3)
Sewage/Graywater Screening Solids	Solids generated by the vibratory screen of the ROCHEM sewage/graywater treatment system. Screening solids are pumped from the filter's solids collection tank to a double-bottom holding tank for discharge outside of 12 nm from shore.	SP-20	Sample tap was installed on the pipe that transfers screening solids from the filter's solids collection tank to the double-bottom holding tank.	Flow measurements not required. Approximately 50 gallons of sewage/graywater screening solids are generated per day, according to the ship's crew.	1 (Day 3)
Sewage/Graywater Waste Biosludge	Waste biosludge removed daily from the bioreactors of the ROCHEM sewage/graywater treatment system. Waste biosludge is pumped to a double-bottom holding tanks for overboard discharge outside 12 nm from shore.	SP-21	Sample tap was installed on the pipe that transfers waste biosludge from the bioreactors to the double-bottom holding tank.	Flow measurements not required. Approximately 25 m^3 of waste biosludge is generated per day, according to the ships crew.	1 (Day 3)

(a) See Figures 2-1, 2-2, and 2-3 for simplified diagrams of the Oosterdam graywater and sewage CHT and treatment systems indicating the sampling point and flow meter locations.

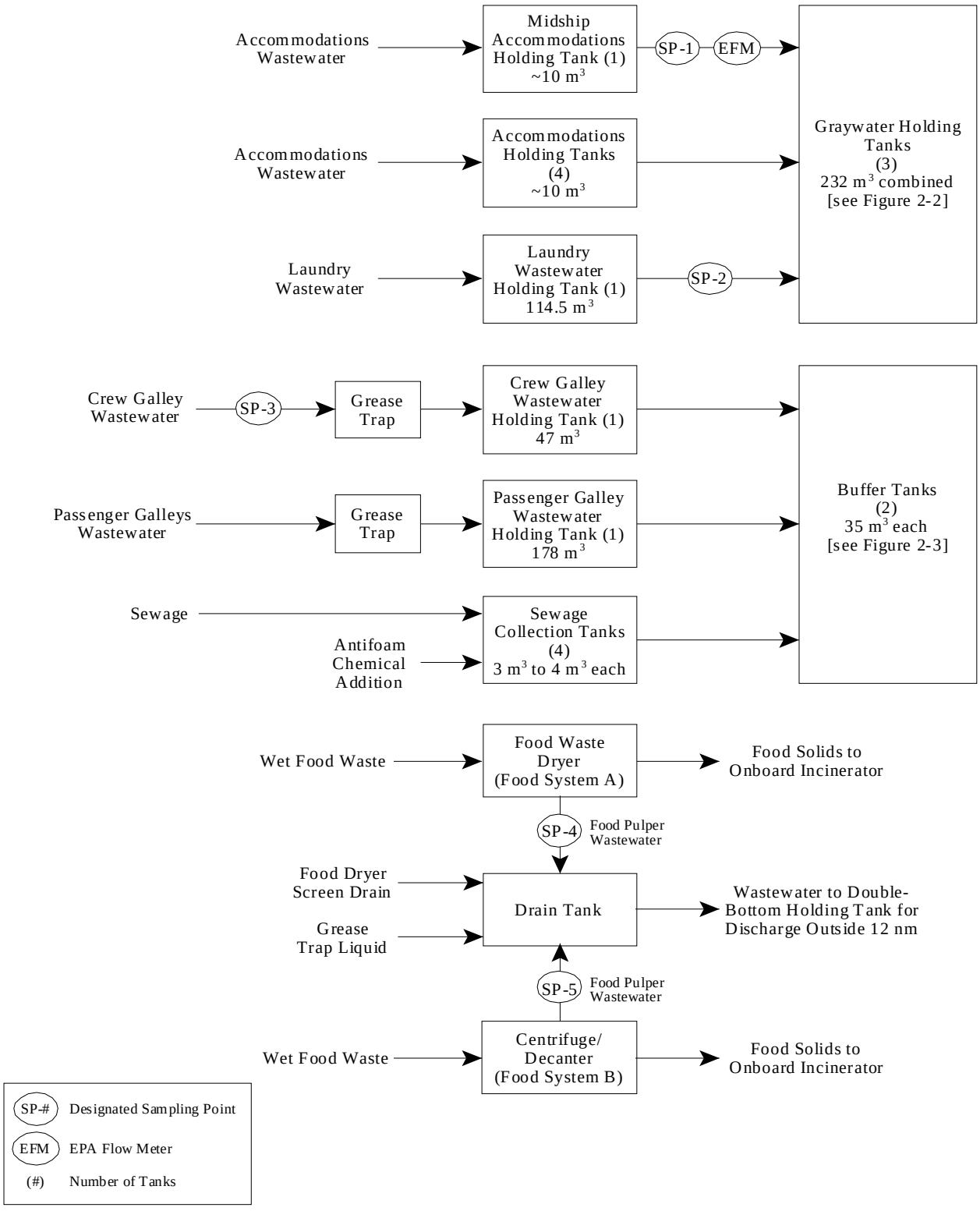

Figure 2-1. Graywater and Sewage Collection, Holding, and Transfer System - Holland America Oosterdam

Simplified diagram of the Holland America Oosterdam graywater and sewage CHT system. See Table 2-1 for a list of wastewater streams in each wastewater source.

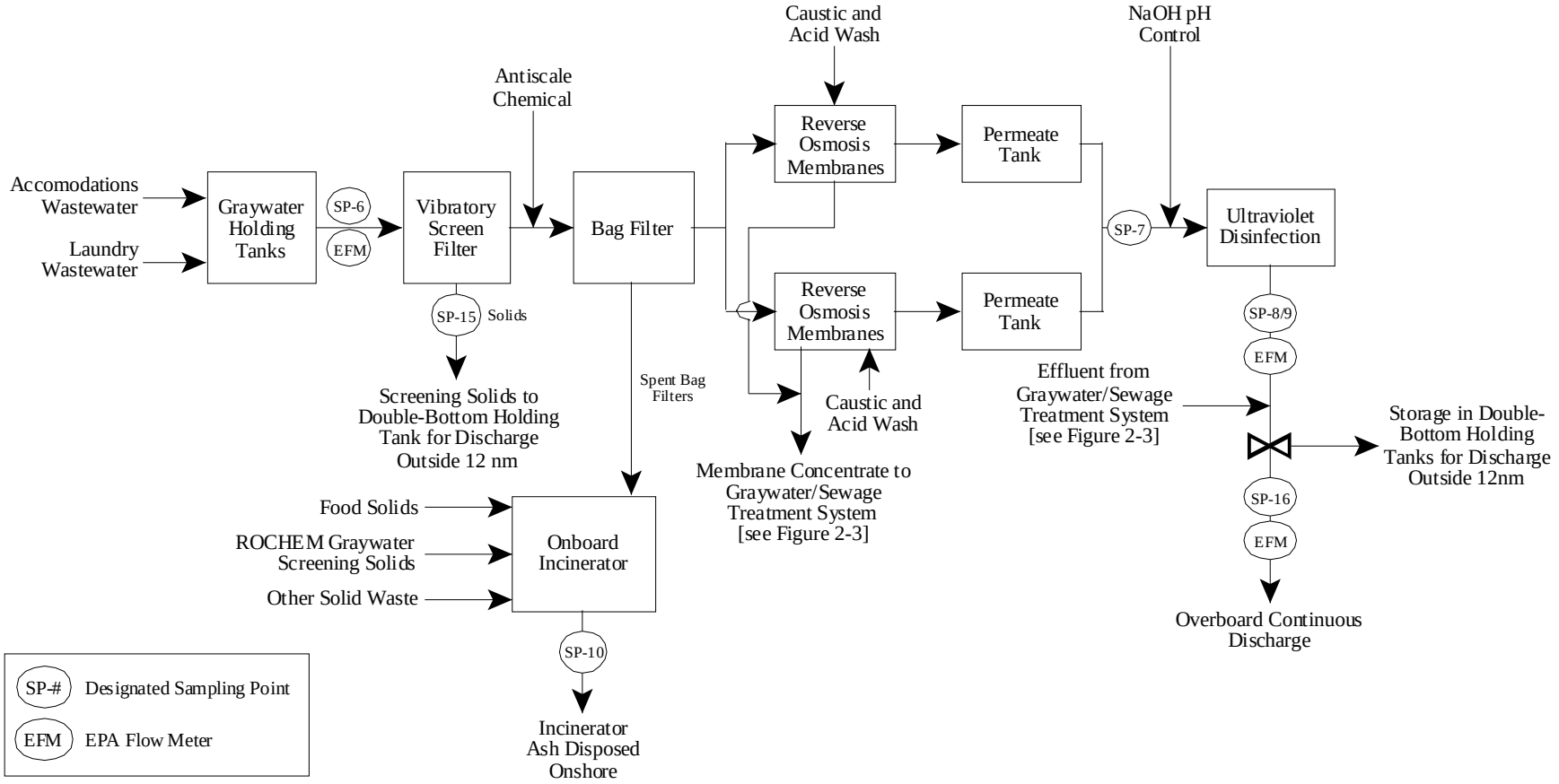

Figure 2-2. ROCHEM Graywater Treatment System - Holland America Oosterdam

Simplified diagram of the Holland America Oosterdam ROCHEM graywater treatment system. See Table 2-1 for a list of wastewater streams in each wastewater source, and Figure 2-1 for their collection and conveyance to the treatment system.

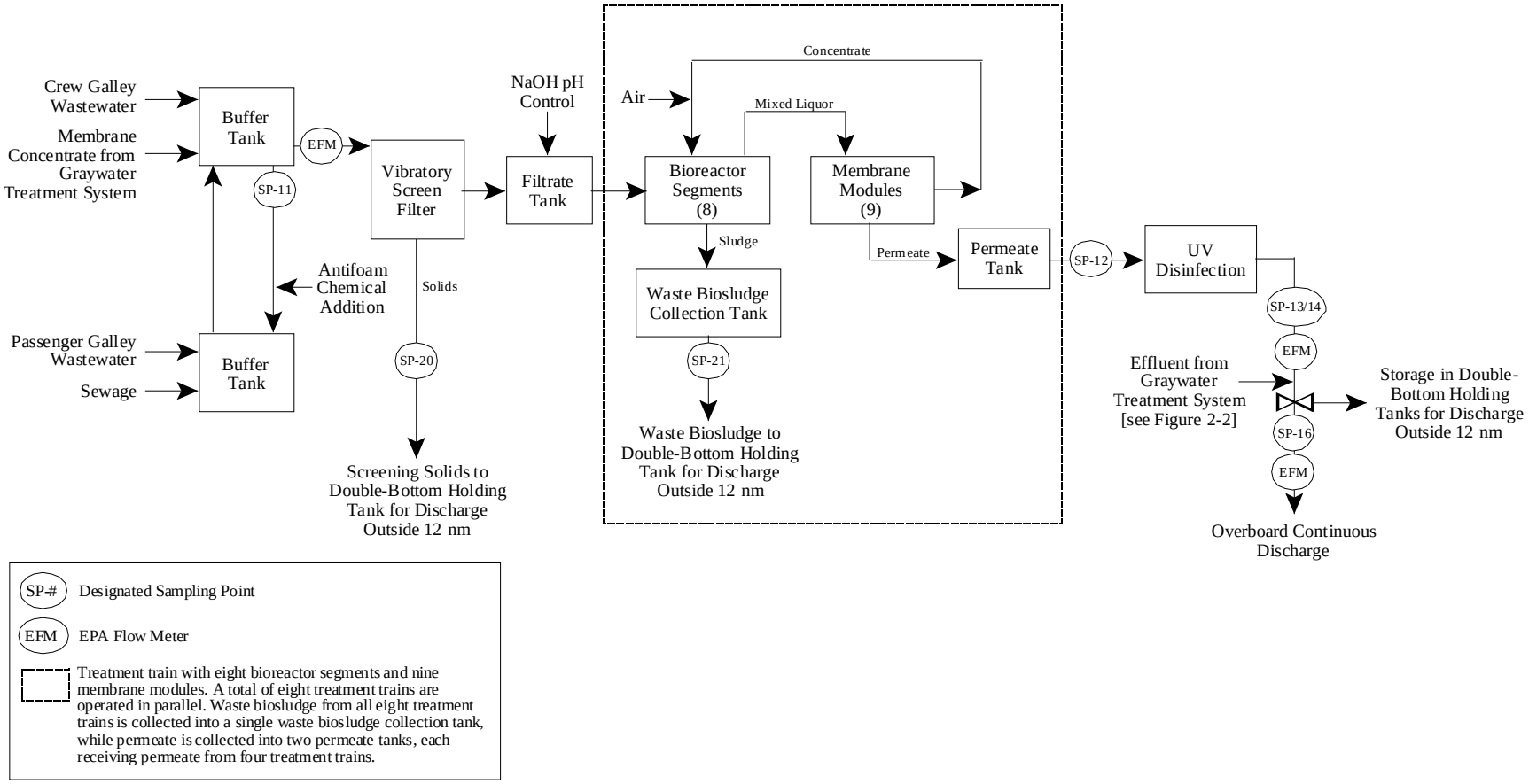

Figure 2-3. ROCHEM Sewage/Graywater Treatment System - Holland America Oosterdam

Simplified diagram of the Holland America Oosterdam ROCHEM sewage/graywater treatment system. See Table 2-1 for a list of wastewater streams in each wastewater source, and Figure 2-1 for their collection and conveyance to the treatment system